CHAPTER 7
COMPONENT QUALIFICATION

Component qualification requirements and procedures for specific component qualification tests are identified. Also identified are the component types that normally undergo component qualification.

7-1 INTRODUCTION

The objective of component qualification is to ensure within reason that the components meet or exceed the specified performance. A component can be airworthy but not necessarily qualified. More often than not, components are not qualified prior to first flight. Early identification of operational suitability and performance deficiencies allows time for the development process to correct the deficiencies. Qualification tests should be performed on production or near production hardware. Performing component qualification at the component level may be the only practical level at which a certain performance characteristic can be demonstrated. This is particularly true for tests requiring the use of laboratory equipment that could not practically accommodate a subsystem or system. Except for flight safety parts (FSPs), component qualification facilitates parts standardization in that a qualified component may be used in other applications if it can be shown that the new application is sufficiently similar or equivalent to the application for which the part has been qualified.

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7-2 QUALIFICATION REQUIREMENTS

Component qualification requirements are based on the criticality of their application in a specific air vehicle design and on the anticipated environmental conditions to which the component will be subjected. The types of components and the types of component qualification tests that may be performed on these components are addressed in the subparagraphs that follow.

7-2.1 TYPES OF COMPONENTS

Components are usually grouped according to the general function of the components, the subsystem to which the components belong, or the functional application of the component. Table 7-1 presents typical functional-application-component-type groupings along with examples of components belonging to those groups. Components can be one piece or an assembly. For example, an oil pump assembly, bearing assembly, shaft assembly, gear assembly, and filter assembly are all components of a transmission assembly. A transmission assembly is a component of the transmission and drivetrain assembly.

7-2.2 TYPES OF TESTS

The types of component qualification tests to be discussed later in this chapter are functional tests, structural tests, endurance tests, and environmental tests. An introduction to these tests follows:

1. *Functional Tests*. Functional tests involve the demonstration of specified performance requirements and operational characteristics. Form, fit, and function should be validated.

2. *Structural Tests*. Structural tests demonstrate the structural integrity of a component prior to its installation in the air

TABLE 7-1. QUALIFICATION COMPONENT TYPES

COMPONENT	EXAMPLES
Structural (including dynamic components)	Rotor blades Driveshafts Castings Crew seats
Electromechanical	Generator (alternator) Fuel boost pump Oil cooler fan Rocket or missile launcher
Hydromechanical	Landing gear Oleo strut Flight control actuator Rotor brake Landing gear retraction cylinder
Mechanical	Rotor hub Transmission Overrunning clutch
Electrical	Voltage regulator Anti-icing and deicing element Generator Transformer-rectifier Circuit breaker
Avionic	Radio Intercom Mission computer Navigation equipment Control or display unit Stability or flight control system Weapons processor Armament interface unit

vehicle. Included are such items as castings that form part of the primary structure, armor components, fuel and oil tanks, and transparent areas. For critical dynamic components, determination of the service life based on fatigue loads is the basis for qualification.

3. *Endurance Tests*. Endurance tests show the life adequacy of components subject to wear and/or deterioration with use.

4. *Environmental Tests*. Environmental tests demonstrate that the equipment can be properly stored, operated, and maintained in the anticipated environmental conditions, including the electromagnetic environment.

7-2.3 COMPONENT QUALIFICATION MATRIX

The component qualification matrix provides a way to depict the components that will undergo component qualification and the specific qualification tests to which these components will be subjected. This matrix may be in two parts, one to show preinstallation qualification requirements and one to show preflight qualification requirements. Table 7-2 depicts the combinations of test types for the listed component types.

TABLE 7-2. MATRIX OF COMPONENT AND QUALIFICATION TYPES

	FUNCTIONAL QUALIFICATION TESTS*	STRUCTURAL QUALIFICATION TESTS	ENDURANCE AND SCREENING	ENVIRONMENTAL QUALIFICATION
Structural	1	1	2	
Electromechanical	1	1	2	2
Hydromechanical	1	1	2	
Mechanical	2	1	2	
Electrical	1		2	2
Avionic	2		2	2

*1 = preinstallation requirement
2 = preflight requirement

7-3 QUALIFICATION PROCEDURES

This paragraph describes the general procedures used for component qualification by discussing test specimens, test plans, test reports, qualification by similarity, and the special procedures applicable to flight safety parts.

7-3.1 TEST SPECIMENS

Each component to be tested should be of the production design and should meet design and acceptance criteria. The number of qualification specimens required is determined by the procuring activity (PA) based on the test or tests to be performed. For example, fatigue tests may require more test specimens than an environmental qualification. Use of a component in the qualification test that is not identical to the proposed production design should be approved by the PA.

In some cases preproduction tests will be required. The component configuration should be recorded, including all deviations from the proposed production configuration, in terms of material, process, or dimensions. If it is acceptable to the PA, significant changes may be incorporated into component design during the qualification test program as deficiencies are discovered. In these cases the component configuration used for each of the test specimens in each portion of the qualification test should be recorded. Once a final configuration is obtained, a rerun of some of the tests may be required by the PA. This is discussed further in par. 7-13.

If it is necessary to remove or replace any hardware on the test specimens during any of the tests, the reason for removal should be recorded with an accurate determination of the type of testing the replaced item has undergone. If the item replaced was a normal maintenance or overhaul item that was not expected to last the life of the test component, the qualification should proceed as planned. On the other hand, if the item replaced was one that normally should not fail in service, the design of the item should be reviewed and analysis made to determine whether redesign and retesting are necessary. When retesting is necessary to qualify a redesigned item, the amount of testing is dependent on the reasons of the original failure. If a complete retest is to be conducted using the same basic test component upon which the failure occurred, the chances for failure of some other item in the component undergoing qualification testing are increased, and this fact will be considered if other component part failures are encountered. Throughout development it is important to monitor component configuration and assess the impact of configuration changes on previously conducted qualification tests. If the changes are significant, it may be necessary to repeat certain portions of the qualification. In other instances it may be more practical to assess the impact of the changes during the course of subsystem- or system-level tests.

Validated models may be used as qualification specimens when it can be shown that they provide suitable representation of the actual component. An example of a potential application of a validated model is to replace expensive electronic equipment with ballast if the test requires only a correct weight and center of gravity for those items.

7-3.2 TEST PLANS

Test plans are prepared and submitted in accordance with the contract data requirements list (CDRL) for the components requiring qualification testing. These plans should state specifically the component design parameters to be monitored during the test, the number of specimens to be tested, the test to be conducted on each specimen, the duration and severity of each test, the procedure used to accomplish each test, and a test setup description and identification of the success or failure criteria should be included as appropriate. When environmental tests are a part of the qualification procedure, a functional test should be performed before, during, and after the environmental test to determine whether there has been any significant degradation in performance.

7-3.3 QUALIFICATION REPORTS

Qualification reports, submitted in accordance with the requirements of the CDRL, describe the procedures used to conduct component qualification and the conclusions of the component qualification. The reports are prepared for both qualification tests and qualification analyses. They describe the component and its application, its performance requirements, and the basis for the determination that the component has been successfully qualified. Qualification report formats are generally specified in a data item description (DID).

7-3.4 QUALIFICATION BY SIMILARITY

In some cases it is possible to use components in an air vehicle system that have been used on a previously qualified air vehicle. These systems or components may be used in their off-the-shelf configuration or with some minor modifications to make them compatible with the new model.

If an off-the-shelf product is used on the new air vehicle and the design requirements are the same as or less severe than the previous installation, the component is considered qualified, and no new tests are necessary. If the design requirements and/or operating conditions are more severe, requalification of the component is required. When required, requalification should address only those tests necessary to show that the component will perform adequately under the new requirements. Similarity alone cannot be used to qualify flight safety parts.

Category I similarity consists of those components used in a new design that are identical to components used in a previous design and have identical operational and environmental requirements. Category II similarity refers to components in a new design that have minor modifications to components used in previous designs and/or have similar operational and environmental requirements. Category III similarity applies to components that have been used in similar design applications by other contractors.

The method of qualification proposed by the contractor is subject to the approval of the procuring activity.

7-3.5 SPECIAL PROCEDURES FOR FLIGHT SAFETY PARTS

It is the policy of the US Army to acquire high-quality, proven, reliable, and safe flight safety parts. Flight safety parts that require engineering testing (fatigue, endurance, interchangeability, etc.) are procured only from sources whose part has met the engineering test requirements. In addition, a flight safety part must undergo an acceptable inspection, as indicated in Chapter 3. The processes used to identify and qualify FSPs are also described in Chapter 3. All inspection records should identify the specific FSPs and critical characteristics inspected and record the results of measurements and/or inspections, the date of inspection, the identity of the inspector, and the required inspection certification. When FSPs are required to be serialized, all operations and inspections affecting a critical characteristic should be traceable to the serialized item.

7-4 PARTS CONTROL PROGRAM

A parts control program (PCP) provides a means to reduce the proliferation of parts within the Department of Defense (DoD) by ensuring a new part is not designed if one already exists in the inventory that will meet the requirements. MIL-HDBK-402, *Guidelines for the Implementation of the DoD Parts Control Program*, (Ref. 1) provides assistance for implementation of a parts control program and contains the information considered necessary to tailor or streamline effectively the PCP requirements to suit specific acquisitions.

One of the advantages of using parts from a Qualified Products List (QPL) is that the testing for that part or component has already been performed; thus that cost need not be incurred again. However, it is necessary to determine the qualification level of the standard part and assess the degree to which the previously performed qualification testing satisfies the new requirements for the part. Partial requalification may be required to ensure that the part is fully compatible with the new application.

7-5 FUNCTIONAL QUALIFICATION TESTS

Functional qualification tests are discussed in this paragraph. Table 7-3 shows examples of functional tests and specifications for various component types.

TABLE 7-3. FUNCTIONAL QUALIFICATION TESTS

COMPONENT	FUNCTIONAL QUALIFICATION TEST	EXAMPLE* SPECIFICATION OR STANDARD
Fuel Pump	Flow rates, pressures	MIL-F-8615
Hydraulic Tubing	Strength, fittings	MIL-H-8775
Pneumatic Valves	Proper actuation at specified pressures	MIL-V-38398
Electrical Connectors	Insulation resistance, contact resistance and retention, EMI shielding, etc.	MIL-STD-1344

*Commercial standards and specifications suitable for the intended purpose should be used in lieu of the military standards and specifications. Otherwise, a waiver is required from the Milestone Decision Authority.

7-5.1 PURPOSE

The purpose of a functional qualification test is to demonstrate that the component complies with specification performance requirements. Functional qualification tests are performed to permit measurement of component performance parameters. The tests are conducted and documented so that each performance parameter or combination of parameters, as required, is exercised to its maximum capability.

7-5.2 DETAILED REQUIREMENTS

Detailed functional qualification test requirements are stated in the general specifications for the type of component being considered or are defined by the contractor based on subsystem specification requirements. Functional testing should be conducted under conditions that duplicate service conditions as closely as possible

7-6 STRUCTURAL QUALIFICATION TESTS

Structural integrity qualification requirements, static and fatigue loading requirements, special requirements of composite material structural testing, and crash resistance requirements are discussed in the subparagraphs that follow.

7-6.1 STRUCTURAL INTEGRITY PROGRAM

The contractor should be required to describe the program used to ensure that structural integrity receives attention from concept definition through design, testing, and operation of rotorcraft systems. . approach to achieving structural integrity throughout the life cycle is the Helicopter Structural Integrity Program (HSIP). The elements of the *Helicopter Structural Integrity Program (HSIP), Vol. I, Structural Test Requirements Specification*, (Ref. 2) are structural design criteria (which include materials and processes), analysis and test of design (fatigue integrity), structural integrity verification, and operational data acquisition and data management requirements (structural integrity maintenance) for rotorcraft. MIL-STD-1530, *Aircraft Structural Integrity Program, Airplane Requirements*, (Ref. 3) describes an equivalent structural integrity program for Air Force systems (called Aircraft Structural Program (ASIP)), with the addition of sonic effects.

Most contractors have a similar, although not identical, program to achieve structural integrity throughout the life cycle. Also the contractor should be encouraged to establish the philosophy for structural design of each load component as either a “fail-safe” or “safe-life” component. Neither the Army nor any contractors for the Army have ever qualified a component, subsystem, or system using the “total-life” concept. For additional information, see *Foundations of an Army Helicopter Structural Integrity Program* (Ref. 4). For additional information concerning composite materials, see subpar. 7-6.4 and ADS-35, *Composite Materials for Helicopters* (Ref. 5).

7-6.1.1 Structural Design

Detailed structural design criteria for the specific rotorcraft and components should be established by the contractor in accordance with the requirements of the specification. The specification typically contains design criteria for strength, damage tolerance, durability, flutter, vibration, weapons effects, etc. The contractor should convert these detail design criteria into actual limit load conditions. For additional information, see ADS-29, *Structural Design Criteria for Rotary Wing Aircraft* (Ref. 6) and MIL-STD-1530 (Ref. 3). Normally, the loads are related to structural design gross weight (SDGW) or maximum alternate gross weight (MAGW). These terms are defined in Ref. 4. Definitions of structural failure for metallic and nonmetallic components for both limit load and ultimate load tests are in HSIP, Vol. I. Material strengths should be based on MIL-HDBK-5, *Metallic Materials and Elements for Aerospace Vehicle Structures*, (Ref. 7) MIL-HDBK-17, *Plastic for Aerospace Vehicles, Part 1, Reinforced Plastics,* (Ref. 8) or other sources approved in advance by the PA. Typical other sources include coupon tests of composite materials for which no strength data are available.

Damage tolerance is defined by HSIP, Vol. I, (Ref. 2) and MIL-STD-1530 (Ref. 3) as the ability of a structure to resist failure due to the presence of flaws, cracks, or other damage for a specified period of unrepaired usage. Damage tolerance is typically achieved by means of redundant load paths, low stress levels, good fatigue characteristics, and slow crack propagation rates. Additional information on damage tolerance is included in *The Fundamentals of Aircraft Combat Survivability and Design* (Ref. 9).

Durability of the rotorcraft structure is defined by HSIP, Vol. I, as the ability of a structure to resist cracking (including stress corrosion and hydrogen-induced cracking), corrosion, thermal degradation, delamination, wear, and the effects of foreign object damage for a specified period of time.

The rotorcraft system specification and structural design criteria should address prevention of static and dynamic aeroelastic instabilities. However, static and dynamic aeroelastic instabilities cannot be addressed at the component level.

Detail structural criteria should include as a performance requirement that component natural frequencies w_n (as installed) should not be coincident with the forcing frequencies w_f of the rotorcraft. Analyses should show that structural components have been designed so that natural frequencies w_n are not coincident with forcing frequencies w_f (Ref. 10). Generally, a 10 percent frequency margin is required. As a minimum, flutter analyses for all lifting surfaces should be performed by the contractor to verify these tolerances, and stability testing should also be performed as required.

The contractor should analyze the effects of vibration on structural integrity. Vibration transmitted to the structure from the rotor systems should be treated as a superimposed load since Ref. 10 cites these vibrations as the cause of many structural cracks. Preliminary analyses are used later to compare with actual rotorcraft vibration to validate those analyses and update them as necessary.

Weapons effects as the result of operation of armament and blast loads should also be considered superimposed loads. These effects should be considered for loads imposed on the ground and in flight when weapons effects excitations could impact aeroelastic stability margins.

7-6.1.2 Fatigue Integrity

Detailed fatigue integrity criteria and procedures should be established by the contractor based on predicted component loadings. Typical methods of prediction may involve cumulative fatigue damage by Palmgren-Miner cycle-ratio summation theory or Manson's method, (Ref. 11) or other methods proposed by the contractor and approved by the procuring activity. Regardless of the methods used, the contractor should clearly quantify all assumptions used in fatigue life predictions and should submit the fatigue testing plans, procedures, and reports to the procuring activity for approval. These plans and procedures should include provisions for requalification of modified components.

The contractor should continuously monitor the status of fatigue-critical components to ensure that structural integrity is maintained. Ideally, this process should continue from design through the service life of all air vehicles until disposal. As a minimum, this continuous monitoring should take the form of failure analyses of defective fatigue critical components, comparison of assumed and actual flight spectrum loads, and updates to fatigue life predictions required by changes in service use (Ref. 10). Changes in service use are common for rotorcraft since military tactics, operational tempos, and missions may change drastically from development to operation of the systems.

This element of HSIP is similar to structural integrity maintenance with the exception of inspection intervals and procedures and individual rotorcraft tracking. The development of these topics is described in subpar. 7-6.1.4.

7-6.1.3 Structural Integrity Verification

The contractor should ensure that structural integrity of the rotorcraft is verified through tests and analyses prior to first flight and continuously throughout development. Component qualification tests and analyses include but are not limited to determining dynamic frequencies and modes, static strength, fatigue life, and damage tolerance. As mentioned previously, tests and/or analyses should be repeated for components modified as a result of unsuccessful testing.

Typically, first-flight structural integrity requirements include but are not limited to a static test to limit load for critical airframe components, landing gear drop test, ground modal survey and ground resonance shake tests, stress analyses, and a preliminary strength summary and operating restrictions report. As the development flight tests continue, actual flight load spectrum information may require revision of analyses and restrictions.

Following entry into service, additional flight load surveys may be performed as missions and tactics change. This situation is discussed in the following subparagraph.

7-6.1.4 Structural Integrity Maintenance

The contractor should define the means to ensure that the structural integrity of the rotorcraft can be maintained during its intended useful life. The methods used to accomplish this should include individual rotorcraft tracking, updates to flight loads, and failure analyses. Individual rotorcraft tracking can provide information useful to the prediction of structural flaws, determination of inspection intervals, and economic repair criteria. This tracking requires a data collection program that monitors rotorcraft individually throughout their lives. These data management systems should allow the procuring activity to identify flight safety parts (defined and explained in subpar. 3-13), and support surveillance testing of those parts, schedule overhauls, and manage the fleet; the data provided to the contractor should allow a designer to verify and substantiate the design (See Ref. 5.). As a minimum, the history of FSP should be tracked by their serial number. Tracking for each serially numbered component should involve the following information as a minimum:

1. Process, specifications, and materials used
2. Manufacturing inspection procedures
3. Service history
4. Failure data
5. Disposition information.

Additionally, fatigue lives, retirement lives, frequency of inspection, and inspection procedures may need revision once actual flight spectrum loads are identified and/or military tactics, operational tempos, and rotorcraft missions change. The contractor should identify to the procuring activity the significant changes in tactics, operational tempos, and rotorcraft missions that necessitate additional structural analyses and/or flight load surveys.

Failure and damage reports, such as Quality Deficiency Reports (QDRs), should be used to refine inspection intervals and procedures. To ensure that maintenance procedures are maintaining the required level of safety, the contractor should also maintain an active failure analysis and investigation program subject to approval by the procuring activity. This analysis and investigation program should allow the contractor to determine

1. The probable location of fatigue cracks
2. The rate of growth of fatigue cracks (rate of crack propagation da/dN)
3. The length of the crack at which the residual strength is no longer greater than expected loads (Ref. 12).

These data can be used to revise inspection procedures and intervals as needed.

7-6.2 STATIC LOADING

Static load testing should be performed to determine the load-carrying capacity of a structural member in a static condition. Static tests may be conducted to limit loads, ultimate loads, or failing loads. Limit load is the load or load factor that establishes a strength level for design of the rotorcraft; ultimate load is the limit load multiplied by the specified ultimate factor of safety, and failing load is the load at which failure of the structure occurs. A failing load test is advantageous when the location, type, or other details of failure or knowledge of the growth potential of the component is desired. Because a test to limit load is inherent in the other loading conditions, it is usually not specified for qualification unless it is important that the test specimen not be destroyed or unless a check for yielding is all that is desired. The static test of many components is conducted in conjunction with the static test of the airframe.

The main and tail rotor blades are tested for flapwise buckling or bending. Spar, nose cap, trailing edge, and box section components should be tested individually so that the strength properties and methods of failure can be determined.

Although fatigue is a critical aspect for rotor system dynamic components, static load tests furnish useful information on strength properties and load distribution. Examples of dynamic components that would undergo static loading tests are pitch links and arms, swash plates, drive links, fixed links, rotor hubs, masts, and pitch housings.

The basic test for flight control components is the proof load and operation test, which demonstrates that the systems will not deflect excessively, bind, or otherwise interfere with each other, with other components, or with the airframe while operated throughout the full range of travel and under design limit loads. The test also applies to the hydromechanical portions of the fly-by-wire systems. Both the pilot's and copilot's controls should be loaded and applied loads reacted at the blades and control surfaces. The controls should be cycled through their full range of travel with the limit loads applied, and the number of times cycled should be kept to a minimum because of the danger of low-cycle fatigue.

Rotor and control actuating cylinders should be subjected to proof pressure tests for leaks, loosening of components, and permanent deformation. In addition, limit and ultimate column loads, tension loads, and compression loads should be applied to the actuating cylinder at the output and inlet ports. Column load tests are accomplished with the cylinders in the most critical position. The actuators should be inspected for static and dynamic leakage after the limit load test.

Static testing of the transmission and gearbox housing should include ultimate load for critical nonflight (e.g., crash) conditions and failing load for the critical flight condition.

Class 1A castings, i.e., castings in which a single failure would cause loss of the rotorcraft, should be static tested to failure for critical loading conditions for which a casting factor of safety less than 1.33 is shown. Due to the unreliability of castings and the inherent scatter of casting test results, three casting specimens should be tested (usually the least acceptable ones), and a minimum casting factor of safety of 1.25 should be demonstrated at the ultimate load.

The performance requirements for crashworthy components (which include fluid system components) should be validated by statically and dynamically using the test methods of MIL-STD-1290, *Light Fixed and Rotary Wing Aircraft Crash Resistance*, (Ref. 13).

ADS-24, *Structural Demonstration*, (Ref. 14) provides useful information concerning demonstrating the structural performance requirements of the rotorcraft. The primary objective of the structural demonstration is to demonstrate the safe operation of the rotorcraft to the maximum attainable operating limits consistent with the structural design, i.e., a static test in the air. The demonstration is conducted after sufficient checkout and buildup flying has been conducted to give reasonable assurance of test completion.

ADS-29 provides useful information about establishing structural design criteria in terms of providing general design requirements, flight load conditions, ground loading conditions, and control system loads. The design criteria include maneuver conditions and flight procedures that may be used during the structural demonstration as part of the qualification process.

7-6.3 FATIGUE LOADING

A large number of rotorcraft components are fatigue critical. This means that their structural adequacy is based on a stated service life when subjected to repeating cycles of alternating load rather than on a positive margin of safety under critical static loads. Qualification of a fatigue-critical component requires determination of its service life, either finite or infinite, or demonstration of adequate fail-safe characteristics.

Fatigue testing should be performed on all critical, primary, structural, load-carrying components. The required testing should be sufficient to provide data adequate for service life determination or to demonstrate acceptable characteristics. Components to be tested include these:

1. *Main Rotor System*. In the main rotor system the components are obtained from the critical areas, the number of which is dependent on the rotor configuration. Critical-area components include the hub-to-mast attachment, actuators, swash plates, hub-to-blade root attachment, centrifugal tension-torsion strap, and a basic blade section. Additional areas of testing in the main rotor blade may be required due to concentrated mass areas, such as tip weights or antinode weights, which provide rapid change in section properties with resultant local stress concentrations. Each area of the

main rotor system should be considered thoroughly in the design stages and analyzed and identified to ensure the critical areas are included in the test program.

2. *Antitorque Rotor System*. This system is similar to the main rotor system, and the components selected for fatigue testing should be based on the identified critical areas. Fatigue testing should be conducted on the hub, blade root end, tension-torsion reaction system, and basic blade section.

3. *Main Rotor Control System*. Fatigue testing of the control system components forward of the boost system (if installed) usually is not required because such a system isolates the oscillatory loads that originate in the rotor system. Fatigue testing should be performed on all components from the boosters up to and including the pitch control arm. In the absence of a control boost system, all control system components subject to critical fatigue loading should be fatigue tested.

4. *Antitorque Rotor Control System*. This system is similar to the main rotor control system; fatigue testing should be performed on all components from the booster system to the pitch control arm or on all components subject to critical fatigue loading.

5. *Power Drive Systems*. Fatigue testing of the power train system components should be accomplished and should include the main rotor mast, transmission input shaft, antitorque rotor driveshaft, miscellaneous power takeoff shafts, and gear flanges.

6. *Transmission, Gearbox, and Associated Components*. Fatigue testing of the basic gearbox case, other critical gearbox housings, and their local supporting structure should be accomplished. Also qualification testing of gears, shafts, etc., typically includes but is not limited to fatigue testing at 125% of the normal rated torque while installed in the gearbox assembly. Usually, 10 million cycles at overload torque are accomplished.

7. *Engine Mount*. Any portions of the engine mounting system, including airframe-mounted attachments determined to be fatigue critical during the flight load survey, should be fatigue tested.

8. *Other Components*. Fatigue tests should be conducted on any other structural component for which fatigue loads are found to be critical. Attachments and mountings, such as those for horizontal and vertical stabilizers, landing gear, and armament, should be investigated during the flight load survey to determine the need for additional fatigue tests. Particular attention must be given to analytically identifying the mountings located in the antinode vicinity of the fundamental fuselage modes. Location of such mountings should then be confirmed by vibration test.

The laboratory fatigue test of rotorcraft components can be accomplished in various ways. The methods used most often are spectrum and S-N testing, i.e., testing that results in curves of stress versus number of cycles to failure. In spectrum fatigue testing, in-flight load conditions are reproduced as closely as possible. The relative magnitude and distribution of test loads should be based on measured flight loads. Because the flight load survey may not be completed when the fatigue test program is initiated, the first tests may be started with loading conditions based on computed loads or the flight loads measured on prototype hardware.

The test parts should be instrumented with strain gage locations identical to those used in flight test. Strain gages are not required if the test loads applied to the components can be verified with acceptable accuracy by other means. Oscillatory loads should be applied to each specimen in increments of the measured flight loads; the load distribution should be representative of all flight conditions. In some cases it may be necessary to superimpose gust loads on the fatigue loading spectrum.

The preferred method of fatigue testing is the S-N technique because service lives can be determined from S-N data for any load condition. Variables that significantly influence the test results, such as number of specimens, methods of applying loads, and data scatter limits, should be approved by the procuring activity.

Because spectrum testing involves reproducing in the laboratory load amplitude and frequency distributions directly proportional to those encountered in flight, it may be considered a more exact basis for the initial determination of service life. However, it is not possible to determine whether alteration of mission profiles or the frequency of alternate missions, or any other change in the air vehicle flight spectrum has an effect on the component service life without retesting in the altered spectrum. Therefore, spectrum testing, should be used only when specifically approved by the procuring activity.

Fatigue test specimens should be of production configuration and quality. The number of specimens to be tested should be proposed by the contractor and approved by the procuring activity.

Comparison of available fatigue test data with the effect of loading frequency on metallic materials indicates that tests conducted within a frequency range factor of 10 gives similar results. Test load frequency of application, therefore, should be kept within a factor of 10 of the normal operating frequency of application.

For the main rotor normal operating frequency (one per rev) is dependent on the rotor rotational speed and usually ranges from 4 to 8 Hz. The tail rotor frequency (also one per rev) usually is in the range of 15 to 30 Hz.

Each fatigue test setup has unique features based on the design of the air vehicle. For example, rotor system components may be subjected to four loads simultaneously: centrifugal force, flapwise bending, chordwise bending, and torsion. Loadings should be verified by analysis and by use of strain gages installed on the component, as appropriate. Force and moment distributions should be verified during testing and compared with design and flight distributions.

Most critical areas are located at joints or transitions. Strain gages, however, should be located in relatively uniform sections. Installations adjacent to joints and/or rapid transitions should be avoided because these local stress concentrations will influence the strain gage output and result in improper readout.

Use of stress analysis techniques such as stress coat, photo stress, and plastic models should be encouraged. These techniques are not used for detailed analysis but to determine rapidly the critical areas and approximate strain magnitudes. These critical areas can then be checked with appropriately located strain gages.

ADS-24 (Ref. 14) provides information useful to determining the structural demonstration criteria, and ADS-29 (Ref. 6) provides information useful to determining structural performance criteria for rotorcraft. The data obtained during this demonstration are used to verify that loads used in the structural analysis and static tests are not exceeded during flight and to substantiate fatigue life calculations.

7-6.4 COMPOSITE STRUCTURES

Structural testing of composite components is essentially the same as for metallic structures, except environmental factors and filament direction are of greater significance. Also, for each composite material to be used, the contractor should be required to determine the design allowables necessary to support the design and performance requirements of the contract. The contractor should be required to submit the properties data along with a summary of qualification test procedures, number of specimens, etc. If these properties are not known, the contractor should perform tests to determine the physical, mechanical, chemical, thermal, and electrical properties. Susceptibility to nuclear, biological, and chemical (NBC) agents and decontaminates should be part of chemical properties testing. ADS-35 (Ref. 5) provides additional information relevant to qualification testing of composite materials. Also see par. 7-14 through subpar. 7-14.4.

In fatigue testing of composite structures special care should be taken to select load application frequencies for laminated and bonded structures that ensure there is no excessive buildup of temperature leading to premature bond line failures.

7-6.5 CRASH RESISTANCE

Crash resistance tests are performed to demonstrate that systems are designed to prevent occupant fatalities and to minimize the number and severity of injuries during crash impacts. The procuring activity should define the performance and validation requirements for crashworthiness. MIL-STD-1290 (Ref. 13) provides relevant information. These criteria are usually specified for military rotorcraft but not for Federal-Aviation-Administration (FAA) - certified air vehicle. Crashworthiness of the systems that follow is validated by test:

1. Fluid fuel systems
2. Crew seats
3. Troop and passenger seats
4. Litter supports
5. Landing gears
6. Flammability tests of selected airframe and interior materials.

Tests and test methods include such items as static and dynamic tests on frangible devices, instrumented drop tests on landing gears to verify attenuation and loading strength characteristics, and rotorcraft system testing to verify analysis and substantiate system capability to prevent fatalities and minimize injuries.

7-7 FAA STRUCTURAL QUALIFICATION

This paragraph addresses the Federal Aviation Administration requirements for component structural testing and design of air vehicles. The agents of the FAA certify only that requirements have been satisfied.

7-7.1 STRUCTURE

The airworthiness standards of the FAA for aircraft, which are Parts 23 and 25 of Title 14 of the Code of Federal Regulations, (Refs. 15 and 16) establish strength requirements in terms of limit load (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by a prescribed factor of safety). These regulations require that compliance with the strength requirements be shown for each critical load condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, substantiating load tests must be performed. Dynamic tests, including structural flight tests, are acceptable if the design load conditions have been simulated.

7-7.2 DESIGN AND CONSTRUCTION

Federal Aviation Administration airworthiness standards for design and construction of several categories of aircraft are included in Parts 23 and 25 of Title 14, Code of Federal Regulations (Refs. 15 and 16). These standards provide proof of strength requirements for various components. For wings, proof of strength must be accomplished by load tests or by combined structural analysis and load tests. For control surfaces, limit load tests are required. These tests must include the horn or fitting to which the control system is attached. For control systems, compliance with limit load requirements must be shown by tests in which

1. The direction of the test loads produces the most severe loading in the control system.
2. Each fitting, pulley, and bracket used in attaching the system to the main structure is included.

Compliance must be shown by analyses or individual load tests with the special factor requirements for control system joints subject to angular motion. For the landing gear, it must be shown that the limit load factors selected for design for takeoff and landing weights, respectively, will not be exceeded. Compliance must be shown by energy-absorption tests except that analysis based on tests conducted on a landing gear system with identical energy absorption characteristics may be used for increases in previously approved takeoff and landing weights. The landing gear may not fail but may yield in a test showing its reserved energy-absorption capacity simulating a descent velocity of 1.2 times the limit descent velocity if wing lift is equal to the weight of the air vehicle.

7-8 ENDURANCE AND SCREENING QUALIFICATION TESTS

Endurance tests and screening tests are discussed in the subparagraphs that follow.

7-8.1 ENDURANCE TESTING

Endurance tests are performed to demonstrate that wear resulting from normal use will not result in unacceptable performance degradation during a reasonable period of air vehicle operation. For this reason, formal qualification of the components of a new design is not begun until extensive prequalification tests have been completed satisfactorily.

Prequalification tests include investigation of abnormal operating conditions: overspeed, overtorque, oil out, and overpressure. Failure or excessive wear of shafts, bearings, seals, gears, impellers, armatures, and similar items during these tests is cause for design improvements and further testing. Prequalification testing of gearbox assemblies usually includes but is not limited to 200 hours of overstress testing at 125% of normal rated torque, during which time transient limits, overspeed, high temperature, and single-engine capabilities are typically demonstrated. See subpar. 7-6.3 for fatigue testing of gearboxes and related components.

Endurance testing for purposes of qualification usually includes 200 hours of operation while applying a loading profile representing a typical mission. This cycling is repeated throughout the course of the endurance test. Although it provides a good indication of component endurance characteristics, this test may not be able to duplicate adequately the types of interface problems that often cause failures at the system level. Therefore, special care should be used to evaluate such things as structural loads and deflections at critical interfaces.

7-8.2 SCREENING TESTS

Environmental stress screening (ESS) is conducted in order to precipitate and expose latent defects that may have been introduced in the manufacturing and assembly process. These tests are usually conducted on electrical and electronic parts, assemblies, and components in environmental chambers. The test items are subjected to temperature cycling and random vibration cycling. Specific test levels are established in order to provide the most effective screens within the design limits of the test item. The rationale for inducing failures is that if a failure of an item is impending, it is far less costly to uncover the failure in the laboratory environment at the part or component level than to incur a failure with the faulty component after installation in a higher level assembly or after fielding of the system. Because ESS is performed at environmental stress levels higher than those normally encountered, it is important that these stress levels be judiciously selected based on experience with similar components. Too low a level may not produce the desired screening level, whereas too high a level may cause adequately manufactured and assembled hardware to fail.

7-9 GENERAL PHYSICAL ENVIRONMENTS

Environmental qualification testing at the component level is discussed in the subparagraphs that follow. Environmental tests are usually performed in test chambers that expose the test item to a simulated environment singly or to a number of environments simultaneously. Table 7-4 presents the environments normally used for environmental testing and provides a brief purpose of each test. MIL-STD-810, *Environmental Test Methods and Engineering Guidelines*, (Ref. 17) provides a description of specific environmental test requirements and procedures. Specific test criteria contained in the standard may be cited as needed to validate performance. However, the contractor should not be required to comply with this standard in its entirety.

7-9.1 VIBRATION

Vibration testing is performed to identify the structural dynamic properties and to determine the resistance of a component to vibrational stresses expected in its shipment and operational environments. Vibrations can cause wire chaffing, loosening of fasteners, intermittent electrical contacts, touching and shorting of electrical parts, seal deformation, component fatigue, optical misalignment, cracking and rupturing, loosening of particles or parts that may become lodged in circuits or mechanisms, and excessive electrical noise. Vibration testing consists of mounting the test item to equipment that produces the required vibrational environment, exposing the item to a predetermined test level and duration and of operating the item as if it were in operational usage and verifying the ability of the item to function both during and after the test. This procedure is repeated for each of three orthogonal axes.

ADS-27, *Requirements for Rotorcraft Vibration Specifications, Modeling, and Testing*, (Ref. 18) and MIL-STD-810 (Ref. 17) provide methods for specifying, analyzing, and measuring air vehicle vibration environments. Applicable criteria can be used in a solicitation. Also the contractor could be required to propose a test that both duplicates the operational environment and demonstrates satisfactory performance of the component before and

TABLE 7-4. QUALIFICATION ENVIRONMENTS

ENVIRONMENT	PURPOSE
Temperature High temperature Low temperature Temperature shock	Determine the ability of the component to be operated and stored under hot and cold temperature conditions.
Acceleration	Assure that equipment can structurally withstand the expected forces due to acceleration without degradation during and following exposure.
Shock	Determine the ability of the component to withstand the infrequent, nonrepetitive shock of handling, transportation, and service.
Sand and Dust	Determine the ability of the component to be operated and stored in blowing sand and dust.
Gunfire	Determine the ability of the component to withstand and operate under gunfire vibration conditions.
Rain	Determine the effectiveness of protective covers or cases, the ability to perform in the rain. Determine equipment damage or performance degradation caused by the rain.
Humidity	Determine the resistance of the component to a warm, humid atmosphere.
Salt Fog	Determine the resistance of the component to an aqueous salt atmosphere.
Fungus	Assess the extent to which the component will support fungal growth or how fungal growth affects performance.
Icing and Freezing Rain	Demonstrate the ability of the component to operate properly in freezing rain, mist, or sea spray.
Low Pressure (Altitude)	Determine whether components can withstand and operate in a low-pressure environment, such as storage at high altitude, air shipment, and rapid decompression.
Solar Radiation (Sunshine)	Determine the effects of solar radiation on equipment, such as component expansion and contraction, and changes in strength and elasticity.
Vibration	Determine the ability of the component to function within the steady vibration environment to which it will be subjected during its operational life.
Explosive Atmosphere	Demonstrate the ability of equipment to operate in a flammable atmosphere without causing an explosion or to contain such a reaction.
Leakage (Immersion)	Determine whether an item designed to be watertight can be immersed without leaking into its container; determine other possible effects of immersion in water.
Temperature, Humidity, Vibration, and Altitude	Identify the failures that temperature, humidity, vibration, and altitude in combination can induce in electronic equipment.

after exposure. The test duration, amplitude, or both parameters (coincident) could be modified to accommodate reasonable test duration, but actual operational environment and component life must correlate.

7-9.2 TEMPERATURE

The purpose of high-temperature chamber tests is to determine whether components can be stored and operated under hot climatic conditions without experiencing physical damage or performance deterioration.

The purpose of low-temperature tests is to determine whether components can be stored, manipulated, and operated under low-temperature conditions without experiencing physical damage or performance deterioration.

Temperature shock tests are performed to determine whether materiel can withstand sudden changes in the temperature of the surrounding atmosphere without experiencing physical damage or performance deterioration.

High temperatures may temporarily or permanently impair the performance of components by changing the physical properties or dimensions of the material(s) composing them. Examples of problems that could occur as a result of high-temperature exposure are parts binding from differential expansion of dissimilar materials; lubricants becoming less viscous and joints losing lubrication; materials changing dimension either totally or selectively; packing, gaskets, seals, bearings, and shafts becoming distorted, binding, and failing causing mechanical or integrity failures; gaskets displaying permanent set; closure and sealing strips deteriorating; fixed-resistance resistors changing in value; electronic circuit stability varying with differences in temperature gradients and differential expansion of dissimilar materials; transformers and electromechanical components overheating; altering of operating and release margins of relays and magnetic or thermally activated devices; shortened operating life; solid pellets or grains separating; high internal pressures created within sealed cases; and discoloration, cracking, or crazing of organic materials.

Examples of problems that could occur as the result of exposure to cold are hardening and embrittlement of materials; binding of parts due to differential contraction of dissimilar materials and the different rates of expansion of different parts in response to temperature transients; loss of lubrication and lubrication flow due to increased viscosity; changes in electrical characteristics of electronic components, such as resistors and capacitors; changes in performance of transformers and electromechanical components; stiffening of shock mounts; cracking and crazing, embrittlement, change in impact strength, and reduced strength of materials; static fatigue of restrained glass; condensation and freezing of water; decrease in dexterity, hearing and vision impairment of personnel wearing protective clothing; and change in burning rates.

Sudden temperature changes can cause shattering of glass vials and optical equipment, binding or slackening of moving parts, changes in electronic components, electronic or mechanical failures due to rapid water or frost formation, cracking of solid pellets or grains in explosives, differential contraction or expansion of dissimilar metals, deformation or fracture of components, cracking of surface coatings, and leaking of sealed components.

Procedures for high-temperature storage tests consist of installing temperature sensors on, in, and around the test item and chamber; adjusting the temperature of the chamber to the initial test conditions; exposing the item to the specified temperature, time, and cycles; stabilizing the temperature after the last cycle; and conducting a visual and functional checkout of the item.

Procedures for low-temperature storage tests are similar to those described for high-temperature tests.

Procedures for high-temperature operational tests consist of placing the test item in the chamber in its operational configuration, exposing the item either at a constant temperature or a temperature cycle, operating the test item at the high-temperature level, and determining proper operation during and after exposure.

Procedures for low-temperature operational tests are similar to those described for the high-temperature tests except that they include tests of low-temperature manipulation (handling, disassembly, reassembly, and packing) by personnel clothed and equipped as they would be in a low-temperature tactical environment.

7-9.3 ACCELERATION

The purpose of acceleration tests is to assure that equipment can withstand the forces due to acceleration that are expected in the service environment and function without degradation during and following exposure to these forces. Forces induced by acceleration can cause structural deflections that interfere with equipment operation; permanent deformations and fractures that disable or destroy the equipment; broken fasteners and mounting hardware, which can then cause equipment to become loose projectiles, electronic circuit boards to short out and circuits to open up; inductances and capacitances to change values; relays to open or close; actuators and other mechanisms to bind; seals to leak; pressure and flow regulators to change value; pumps to cavitate; spools in servo valves to be displaced and cause erratic and dangerous control system response.

Acceleration tests are performed by placing the test item in either a centrifuge or on a powered sled on a track and subjecting it to the specified level of acceleration, operating it, and inspecting it after the exposure. The test is repeated so that item has been exposed in all six test directions—positive and negative direction of the three mutually perpendicular axes.

7-9.4 SHOCK

The purpose of shock testing is to assure that components can withstand the relatively infrequent, nonrepetitive shocks or transient vibrations encountered in handling, transportation, and service environments. Shock tests are also used to measure the fragility of a component so that packaging may be designed to protect it, if necessary, and to test the strength of devices that attach equipment to platforms which may be subjected to crash loads. Mechanical shocks excite equipment items to respond at both forced and natural frequencies. Among other things this response can cause failures due to increased or decreased friction or interference between parts, changes in dielectric strength, loss of insulation resistance, variations in magnetic and electrostatic field strength, permanent deformation due to overstress, and more rapid fatiguing of materials (low-cycle fatigue).

Shock tests may be classed as functional shock, equipment packaging shock, critical acceleration fragility shock, transit drop, crash hazard, bench handling, pyrotechnic shock, rail impact, and catapult launch and arrested landing. In each case the component is subjected to a series of shocks that represent the intended conditions. These tests are repeated for each of the three axes, and the ability of the equipment to withstand the test is recorded.

7-9.5 SAND AND DUST

The purpose of sand and dust testing is to

1. Ascertain the ability of equipment to resist the effects of dust particles that may penetrate into cracks, crevices, bearings, and joints

2. Determine whether materiel can be stored and operated under blowing sand conditions without experiencing degradation of its performance, effectiveness, reliability, and maintainability due to the abrasion (erosion) or clogging effects of sand particles.

Examples of problems that could occur as a result of exposure of materiel to blowing sand and dust are abrasion of surfaces, penetration of seals, erosion of surfaces, degradation of electrical circuits, clogging of openings and filters, physical interference with mating parts, fouling of moving parts, exothermal reaction (thermite effect) of clay particles (with aluminum oxide) at high temperatures that produces heat which could cause high-temperature corrosion and produce extremely hard, erosive particles.

Blowing sand and dust tests consist of mounting the component in an appropriate chamber; adjusting air velocity, temperature, and particle concentrations to specified levels; operating the items for the specified time period; and inspecting its condition after the test. Areas requiring careful inspection include bearings, grease seals, and lubricants.

7-9.6 GUNFIRE

The purpose of gunfire tests is to assure that the equipment mounted in an air vehicle with onboard guns can withstand the vibration environment caused by the overpressure pulses emitting from the gun muzzle as well as reactive recoil forces. Also the potential for corrosive damage to airframe and engine surfaces attributable to weapon emissions should be investigated. The vibration resulting from repetitive gun blast pulses might be as large as two orders of magnitude above normal flight vibration levels. Gunfire vibration might cause the structure and equipment to respond in a violent manner, and emissions might be ingested directly into the cockpit and engine. This response can cause intermittent electrical contact, catastrophic electrical failures, hydraulic malfunctions, structural fatigue failures, and a possibility of engine failure.

Gunfire tests consist of mounting the test item on a vibration shaker, operating the test item in accordance with its specifications, applying the vibration exposure in accordance with specified levels and durations, operating the item under the vibration exposure conditions, and repeating this process for each of three orthogonal axes.

7-9.7 RAIN

The purpose of rain (water intrusion) testing is to determine

1. The effectiveness of protective covers or cases in preventing the penetration of rain
2. The capability of the test item to satisfy its performance requirements during and after rain exposure
3. The physical deterioration of the test item caused by rain water.

In the atmosphere, rain interferes with or degrades radio communications, limits radar effectiveness, limits air vehicle operations by restricting visibility, damages air vehicles in flight, affects artillery and missile launching, degrades or negates optical surveillance, decreases the effectiveness of personnel in exposed activities, causes some fuzes to function prematurely, and inhibits visibility through optical devices. On impact, rain erodes surfaces. After deposition, water degrades the strength of some materials, promotes corrosion of metals, deteriorates surface coatings, and can render electrical or electronic apparatus inoperative or dangerous. After penetration into containers, water causes malfunction of electrical equipment; may freeze inside equipment, which may cause delayed deterioration and malfunction by swelling or cracking of parts; causes high humidity, which can in time encourage corrosion and fungal growth; and causes slower burning of propellants.

Rain tests may be conducted in blowing rain conditions, drip conditions, or water tightness conditions. In each case the item is placed in an appropriate chamber, exposed to the specified test condition for the appropriate time, and operational checks and visual inspections are conducted during and after exposure.

7-9.8 HUMIDITY

The purpose of humidity tests is to determine the resistance of components to the effect of a warm, humid atmosphere. Typical problems that can result from such exposure are swelling of materials due to moisture absorption, loss of physical strength, changes in mechanical properties, degradation of electrical and thermal properties in insulating materials, electrical short circuits due to condensation, binding of moving parts due to corrosion or fouling of lubricants, oxidation and/or galvanic corrosion of metals, loss of plasticity, accelerated chemical reactions, chemical or electrochemical breakdown of organic surface coatings, deterioration of electrical components, degradation of image transmission through glass or plastic optical elements, absorption of moisture by explosives and propellants, accelerated biological activity, deterioration of hygroscopic materials.

Humidity tests involve placing the test item in an appropriate test chamber, adjusting the chamber to specified temperature and relative humidity conditions, cycling the chamber conditions through specified values, and conducting operational checkouts of the component both during and after the exposure.

7-9.9 FUNGUS

The purpose of fungus tests is to assess the extent to which the component will support fungal growth or how the fungal growth may affect performance or use of the component. Fungal growth impairs the functioning or use of equipment by changing its physical characteristics. This may be in the form of direct attack as the fungi break the material down and use it as food (products of natural origin are most susceptible to this attack) or indirect attack on materials. Damage from indirect attack includes

1. Fungal growth on surface depos its of dust, grease, perspiration, and other contaminants causes damage to the underlying material even though that material may be resistant to direct attack.
2. Metabolic waste products, i.e., organic acids, excreted by fungi, cause corrosion of metals, etching of glass, or staining or degrading of plastics and other materials.
3. The products of fungal growth or adjacent materials that are susceptible to direct attack come in contact with the resistant material.

In addition, fungal growth can cause physical interference with

1. Electronic and electrical systems by creating undesirable electrical conducting paths across insulation materials or may affect the electrical characteristics of critically adjusted electronic circuits
2. Optical systems by adversely affecting light transmission through the optical system, blocking delicate moving parts, and changing nonwetting surfaces to wetting surfaces with resulting loss in performance.

Lastly, fungal growth on equipment can cause physiological problems, e.g., allergies, or be so aesthetically unpleasant that users will be reluctant to use the equipment.

Fungus test procedures involve preparing fungi cultures, applying them to the test specimens and control specimens, incubating the test items for specified time periods, and inspecting them to determine the extent of fungus growth, if any.

7-9.10 ICING

The purpose of icing tests is to evaluate the effect of icing produced by freezing rain, mist, or sea spray on the operational capability of components. A buildup of ice occurs in three principal ways: from rain falling on an item whose temperature is below freezing, from freezing rain falling on an item at or near freezing, or from sea spray that coats equipment when temperatures are below freezing. Ice formation can result in the following problems:

1. Mechanical and vibrational problems from the uneven shedding of ice in rotating components
2. Binding moving parts together
3. Added weight to radar antennas, helicopter rotors, and other airframe components
4. Increased footing hazard
5. Interference with clearances between moving parts
6. Reduced airflow efficiency and sigificantly degraded aerodynamic characteristics of surfaces
7. Impeded visibility through windshields and optical devices
8. Affected transmission of electromagnetic radiation
9. Probability of damage from use of mechanical, manual, or chemical ice removal measures.

Icing test procedures involve stabilizing the test item at approximately 2°C (36°F), delivering a uniform spray of precooled water, lowering the chamber temperature to –10°C (14°F) and maintaining the spray until 6 mm (0.24 in.) of ice has accumulated, adjusting the chamber temperature to –6°C (21°F) for 2 to 6 h, operating the equipment, exercising integral ice removal methods, operating the system again, increasing the ice coating thickness to 13 mm (0.51 in.), and repeating the previous procedures while operating the equipment and its ice removal features.

7-9.11 SOLAR RADIATION (SUNSHINE)

The purpose of a solar radiation test is to determine the effects of solar radiation on equipment that may be exposed to sunshine during operation or unsheltered storage.

The heating effects of solar radiation differ from those of air at high temperature alone because the amount of heat absorbed or reflected depends on the roughness and color of the surface on which the radiation is incident. Some materials may also be susceptible to the solar radiation spectrum and intensity. Solar radiation effects include jamming or loosening of moving parts, weakening of solder joints and glued parts, change in strength and elasticity, loss of calibration or malfunction of linkage devices, loss of seal integrity, changes in electrical or electronic components, premature actuation of electrical contacts, fading of colors of color-coded components, changes in characteristics of elastomers and polymers, blistering and peeling of paints and other finishes, and softening of potting compounds.

Test procedures involve

1. Raising chamber air temperature to a specified level
2. Exposing the test item to continuous 24-h cycles of controlled, specified, simulated solar radiation and dry bulb temperature
3. Repeating the cycles a specified number of times
4. Conducting operational tests and visual inspections.

7-9.12 SALT FOG

Salt fog climatic chamber tests are performed to determine the resistance of equipment to the effects of an aqueous salt atmosphere. Methods to minimize corrosive effects using protective schemes or handling are described in ADS-13, *Air Vehicle Materials and Processes*, (Ref. 19).

The effects of exposure to an environment in which there is an aqueous salt atmosphere can be divided in three broad categories: corrosion effects, electrical effects, and physical effects. Corrosion effects include corrosion due to electrochemical reaction, accelerated stress corrosion, and formation of acidic or alkaline solutions following salt ionization in water. Electrical effects include impairment of electrical equipment due to salt deposits, production of conductive coatings, and corrosion of insulating materials and metals. Physical effects include binding of the moving parts of mechanical components and assemblies and blistering of paint due to electrolysis.

The salt fog test procedure involves adjusting the chamber temperature to 35°C (95°F) and conditioning the test item for at least 2 h. The item is then exposed to a continuous atomized solution of appropriate salt composition for a period of 48 h. The item is then stored in a standard ambient atmosphere for 48 h. At the end of the drying period, the test item is operated and results are documented.

Because of the limited duration of the salt fog exposure, the test is limited in predicting long-term resistance to corrosion and deterioration. Therefore, better test methods to determine corrosion susceptibility for a particular program or application are needed.

7-9.13 EXPLOSIVE ATMOSPHERE

The explosive atmosphere test is conducted to demonstrate the ability of a component to operate in flammable atmospheres without causing an explosion or to prove that a flame reaction occurring within an encased equipment will be contained and will not propagate outside the test item.

Low levels of energy discharge or electrical arc from devices as simple as pocket transistor radios can ignite mixtures of fuel vapor and air. A hot spot on the surface of a hermetically sealed, apparently inert equipment case can ignite fuel vapor and air mixtures. Fuel vapors in compartments can be ignited by a low-energy discharge such as a spark from a shorted flashlight cell or switch contacts.

For testing the operation of a component in an explosive environment, the test involves

1. Preparing the chamber for test
2. Sealing the chamber with the test item mounted inside
3. Raising the chamber temperature to a specified level
4. Adjusting the chamber air pressure to a specified level
5. Injecting the required quantity of *n*-hexane into the test chamber
6. Circulating the test atmosphere to allow for complete vaporization of fuel and development of a homogeneous mixture
7. Operating the test item
8. Increasing the air pressure slowly in the test chamber to simulate an altitude change
9. Checking the potential explosiveness of the air-vapor mixture by attempting to ignite the mixture with a spark-gap or glow plug ignition source
10. Documenting the results.

7-9.14 LEAKAGE (IMMERSION)

Leakage (immersion) tests are conducted to determine whether materiel is constructed to be immersed in water without leakage of the water into the enclosure.

Penetration (seepage) of water into equipment enclosures can result in problems, such as fouling of lubricants between moving parts, formation of electrically conductive bridges (which may cause electronic equipment to malfunction or become unsafe to operate), corrosion due to direct exposure to the water or the relatively high humidity levels caused by the water, and diminishment of the burning qualities of explosives, propellants, and fuels.

The immersion test procedure consists of

1. Opening and closing any doors, covers, etc., that would be opened during normal use to ensure that any seals are functioning properly and are not adhering to the sealing surfaces
2. Conditioning the test item as specified
3. Adjusting the immersion water temperature to the specified level
4. Closing all sealed areas and valves, immersing the test item in water so the uppermost point of the test item is 1 m below the surface of the water
5. Leaving the test item immersed for a specified period of time
6. Removing the item from the water
7. Opening seals and inspecting and operating the item
8. Recording the results.

7-9.15 LOW PRESSURE (ALTITUDE)

The purpose of the low-pressure (altitude) chamber tests is to determine whether materiel can withstand and operate in a low-pressure (altitude) environment. Typically, low-level tests are not intended to test equipment that is to be installed and operated in air vehicles that fly at high altitudes, above 4600 m (15,000 ft). The primary objectives of the low-pressure test are to determine whether the test item can be stored and operated at high ground sites, transported by air in its normal shipping configuration, and survive a rapid decompression.

7-9.16 TEMPERATURE, HUMIDITY, VIBRATION, AND ALTITUDE

Typically, US Army rotorcraft operate below 2100 m (7000 ft); however, many rotorcraft are capable of operating at 6100 m (20,000 ft) and more. Additionally, other US Army air vehicles might operate at 9800 m (32,000 ft) and more. Studies have shown that thermal effects, vibration, moisture, humidity, and in certain cases, altitude have the greatest effect on the life of aviation electronic equipment in the operational environment. Temperature, humidity, vibration, and altitude can interact to produce failures. Hence this test procedure involves application of the combination of temperature, humidity, altitude, and vibration environments to the test item.

7-10 ELECTROMAGNETIC ENVIRONMENTS

The term “electromagnetic environment effects (E^3)” is used to encompass adverse effects due to any source of electromagnetic energy on victim equipment either at the system, subsystem, or component level. Electromagnetic environment is defined as the power and distribution in various frequency ranges of the radiated or conducted electromagnetic emission levels that may be encountered by an equipment, subsystem, or system when performing its assigned mission. This paragraph describes electromagnetic environment tests consisting of electromagnetic interference (EMI) tests, electrostatic discharge (ESD) tests, nuclear electromagnetic pulse (NEMP) tests, lightning tests, and TEMPEST tests.

7-10.1 ELECTROMAGNETIC INTERFERENCE (EMI)

MIL-STD-461, *Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility*, (Ref. 20) can be used as a source of information to establish performance and related criteria for the control of electromagnetic emissions and susceptibility characteristics of electronic, electrical, and electromechanical equipment. An emission consists of electromagnetic energy propagated from a source by radiation or conduction. Electromagnetic susceptibility is the degree to which an equipment, subsystem, or system evidences undesired responses caused by the electromagnetic emissions (radiated or conducted) to which it is exposed.

The associated test document, MIL-STD-462, *Measurement of Electromagnetic Characteristics*, (Ref. 21) can be used as a source of information to establish test criteria needed to verify specified levels of emission and susceptibility. In general, for radiation emissions the tests consist of placing the test sample on a ground plane in a shielded room and operating the equipment throughout its operating modes. Antennas are placed in the room at specified distances either to detect the electromagnetic radiation or generate the electromagnetic radiation. Conducted radiation and susceptibility test procedures vary depending on the specific design requirement being tested. The most common problem in conducting EMI tests is to design test monitoring equipment that is not susceptible to the electromagnetic environment being tested. Fiber-optic links and cable isolation should be used to the maximum extent possible to limit these interferences. Transverse electromagnetic (TEM) cell chambers and reverberation chambers or a chamber that combines both radiation methods may be used for EMI tests. Criteria for using the chambers are discussed in ADS-37A-PRF, *Electromagnetic Environmental Effects (E^3) Performance and Verification Requirements*, (Ref. 22).

ADS-37A-PRF (Ref. 22) establishes the electromagnetic environmental effects performance and interface requirements for implementation at all stages of the life cycle of air vehicle systems and components. ADS-37A-PRF also establishes verification requirements.

7-10.2 ELECTROSTATIC DISCHARGE (ESD)

Equipment performance specifications should also include a requirement that solid-state devices within the equipment must not be susceptible to damage or upset from ESD due to handling of the equipment by operating or maintenance personnel. ESD testing is applicable to solid-state components, conductors, pins, and enclosures exposed during assembly or maintenance actions. ESD tests are intended to demonstrate compliance with this requirement by subjecting the equipment to a specified ESD and verifying that no damage has occurred. Such verification may be difficult because ESD may not cause an immediate failure of the solid-state device. Also embedded processing components are susceptible to ESD. The damage may significantly reduce the life of a component without being immediately detectable. Additional information and criteria are available in MIL-STD-883, *Test Methods and Procedures for Microelectronics*, (Ref. 23).

7-10.3 NUCLEAR ELECTROMAGNETIC PULSE (NEMP)

Electromagnetic pulse (EMP) is the broadband high-power effect encompassing the totality of a system as an antenna, such as would result from a nuclear burst. EMP susceptibility analysis should be conducted to determine that the system is capable of completing its mission in a nuclear EMP environment. The analysis should include the shielding effectiveness of the overall airframe, the shielding effectiveness of cable shielding, and the determination of the responses of electrical connections, including inputs, outputs, antennas, power, and spare pins of mission-essential equipment or functions. EMP tests are intended to demonstrate that a nuclear EMP will not cause permanent damage or hazardous temporary upset to flight-critical functions. Additional information on EMP test procedures is available in the Test Operating Procedures (TOP) 1-2-612, *Nuclear Environment Survivability*, (Ref. 24). (See subpar. 7-12.2 for additional information concerning survivability testing.)

7-10.4 LIGHTNING

Air vehicles are required to survive the direct and indirect effects of a severe lightning strike that either directly attaches to the air vehicle or occurs nearby. Specifically, the air vehicle and its subsystems and components should be designed to satisfy the performance criteria that follow:

1. Prevent hazardous, temporary upset and permanent damage to flight-critical subsystems and components
2. Prevent lightning ignition of fuel and ordnance
3. Prevent catastrophic structural damage to the air vehicle and associated flight-critical subsystems and components that would preclude safe return and landing of the air vehicle
4. Minimize upset and prevent permanent damage to mission-critical subsystems and components so that the mission may be completed.

Lightning tests are intended to demonstrate compliance with these requirements by subjecting components to specified sudden discharge of static electric potential that simulates a natural occurrence in the atmosphere. Typically, the contractor is responsible for the test. Information concerning lightning and lightning tests is included in MIL-STD-1795, *Lightning Protection of Aerospace Vehicles and Hardware*, (Ref. 25). Federal Aviation Administration airworthiness standards for lightning protection of various categories of air vehicles may be found in Parts 23, 25, 27, and 29 of the Code of Federal Regulations, Title 14, *Aeronautics and Space*, (Refs. 15, 16, 26, and 27).

7-10.5 TEMPEST

TEMPEST is a US National Security Agency program designed to provide standards for electronic equipment to protect sensitive data from electronic eavesdropping. The classification of TEMPEST work should be determined and handled in accordance with the DoD Contract Security Classification Specification (DD Form 254). An original DD Form 254, which sets forth the classification specifications or cites the classification guidance, is provided to the contractor as part of the solicitation and award of a contract that necessitates access to classified information. TEMPEST test facilities and testing should comply with the requirements of National COMSEC[*] Information Memorandum (NACSIM) 5100(RP-1), *Comprising Emanation Laboratory Test Requirements*

[*]COMSEC = communications security

Electromagnetic (U), (Ref. 28) and other national security communications security instructions that might be specified in the contract. All personnel assigned to perform TEMPEST work must have a Government-granted final security clearance of SECRET. Typically, the provisions of National COMSEC/EMSEC Information Memorandum (NACSEM) 5112(RP-4), *Nonstop Evaluation Techniques* (U), (Ref. 29) apply to air vehicles at the subsystem level in regard to handling of classified data including hardware and software. NACSEM 5201, *TEMPEST Guidelines for Equipment/System Design* (U), (Ref. 30) and NACSEM 5203, *TEMPEST Guidelines for Facility Design and Red/Black Installations* (U), (Ref. 31) should be used for guidance. Typically, the contractor is required to prepare and submit a test plan for Government approval. The scope of the plan depends on the complexity of the program. After obtaining Government approval of the test plan, facility, and equipment, the contractor conducts the test according to the test plan and submits a TEMPEST report. The US Army Communications and Electronics Command typically evaluates the facility, equipment, test plan(s), and report(s). Additionally, data might be required for TEMPEST evaluation of facility and equipment. Instructions should be provided within the contract.

7-11 OPTICAL/ELECTRO-OPTICAL QUALIFICATION TESTS

The component qualification of optical/electro-optical systems is discussed in the subparagraphs that follow.

7-11.1 TARGETING SYSTEMS

Tests applicable to electro-optical targeting systems include boresight, focus, distortion, transmissibility, uniformity, contrast transfer function (CTF) and modulation transfer function (MTF) tests, minimum resolvable contrast (MRC), minimum resolvable temperature (MRT), and stabilization tests.

Boresight tests are performed to ensure that the optical alignment among the various sensor and designator subsystems of the targeting system is within specification requirements and that the internal boresighting equipment provides the required boresight accuracy. In addition, tests are performed to ensure that the system can retain its boresight during the specified mission duration. Boresight tests may be performed in the laboratory by presenting simulated targets to the various sensors through the use of collimators or in test ranges in which appropriately placed and instrumented targets are observed and designated.

Focus tests are performed to determine the capability of optical subsystem to focus a collimated light source at a desired point in the optical subsystem. Focus tests are performed to determine proper optical alignment and positioning of optical elements.

Distortion is a form of lens aberration that occurs when the magnification of an object line segment varies with its distance from the optical axis of the lens. If the image of a rectangle appears with its sides curved inward, the distortion is called positive, or pincushion, distortion. If the sides curve outward, it is called negative, or barrel, distortion. Distortion tests are performed to determine the extent of such aberrations in an optical subsystem by presenting the subsystem with rectangular targets and observing and quantifying the type and magnitude of distortion.

Transmissibility of optical devices is a measure of the amount of energy passing through the optical elements. Energy incident upon the optical device is attenuated either because it is absorbed by the element or scattered. Transmission of radiation is important because it determines the amount of energy available for detection at the sensor. Transmission is determined by performing radiometric measurements of optical elements.

Uniformity tests are performed to determine display characteristics. Uniformity is a measure of the system to produce equally bright images for equally bright targets at various positions on the display. These tests are performed by performing brightness measurements over the entire display under varying display conditions.

MRT is a laboratory measurement of the lowest temperature difference for a square-wave bar pattern that a thermal imaging subsystem will allow an observer to resolve. This threshold temperature difference is a function of the spatial frequency of the bar pattern. Spatial frequency is measured in cycles per milliradian in object space. MRT tests are normally performed at a given spatial frequency by presenting a bar target to the imaging subsystem and gradually increasing the temperature difference between the pattern and its background. The temperature value at which the observer can discern a modulation within the bar pattern image is recorded as the MRT for the specific spatial frequency. The test is repeated for other spatial frequencies of interest.

MRC is analogous to MRT except that it measures the lowest contrast difference that a system is able to resolve. MRC testing is performed similarly to MRT testing.

MTF is a measure of the resolution of an imaging subsystem. It is the sine-wave spatial frequency amplitude response of the subsystem and equals 1 for sufficiently low spatial frequencies. In general, MTF tests are performed by presenting the targeting sensor with a number of sinusoidally varying target patterns at various spatial frequencies and measuring the response of the subsystem. The usefulness of MTF tests is that the overall performance of an electro-optical system may be determined from the MTF characteristics of its individual components.

The CTF of a system is its square-wave spatial frequency amplitude response. The CTF is easier to measure because it is easier to produce a square-wave optical pattern than a sine-wave pattern. The CTF values of system components, however, cannot be directly combined to produce system-level performance information.

Stabilization tests are performed to determine the capability of the electro-optical system to meet its performance requirement in the specified vibration environments. Line-of-sight angular motion results in MTF degradation and in undesirable motion of the laser spot in systems incorporating laser designation. Stabilization tests are performed by placing the sensor on a shaker platform and measuring the resulting line-of-sight angular motions while being shaken and before and after being shaken.

7-11.2 PILOTAGE SYSTEMS

Pilotage electro-optical systems are similar to targeting electro-optical systems in terms of the types of performance parameters requiring component-level testing. Major differences are that pilotage systems may include special requirements for the detection of hazards, such as wires, poles, and other obstacles. Additionally, line-of-sight stabilization requirements are normally much less stringent for pilotage systems than for targeting systems.

7-12 SURVIVABILITY QUALIFICATION TESTS

This paragraph addresses ballistic, directed energy, nuclear, and NBC threat testing of systems, subsystems, components, and materials. All of these threats are capable of affecting mechanical, structural, electrical, and electronic components. Typical test requirements are summarized in subpars. 7-12.1 through 7-12.4. Additional information concerning ballistic hardening, analyses, and tests; directed energy threats, tests, and vulnerabilities; nuclear hardening, electromagnetic pulse, neutron fluence, total dose, peak gamma dose rate, thermal radiation, nuclear air blast, and demonstrations; and NBC analyses, tests, and demonstrations may be found in ADS-11, *Survivability Program, Rotary Wing*, (Ref. 32).

7-12.1 BALLISTIC TESTS

Components, subsystems, and an air vehicle should be subjected to ballistic firing tests, controlled damage tests, and a vulnerability reduction demonstration as provided for in MIL-STD-2069, *Requirements for Aircraft Nonnuclear Survivability Program*, (Ref. 33). Typically, ballistic tests are performed by subjecting the specimens to impact by projectiles of a specified type at a specified velocity and orientation and by determining the capability of the specimen to prevent penetration in the case of protective materials, such as armor, or to retain its integrity in the case of structural components. In addition, component-level tests may be performed to determine the capability of components to operate safely after loss of lubrication, which may result from ballistic damage. Damage might also occur to flight-critical avionic systems and components, such as computers and processors. The contractor typically selects the components, subsystems, and air vehicle and specifies the proposed test program in the Airworthiness Qualification Specification (AQS).

7-12.2 DIRECTED ENERGY TESTS

For the purposes of this handbook, directed energy weapons are limited to battlefield lasers and the high-power microwave. The battlefield laser threats and related performance requirements usually are described in the system specification and may include several types of weapons. The directed energy hardness should be validated through component and subsystem tests. Demonstrations at the air vehicle system level would also be appropriate. The tests should be conducted on actual or simulated components (same material and design as the actual components) and on complete subsystems or portions thereof. The vulnerability reduction substantiation, verification, and demonstration tests should be integrated and piggybacked on endurance-, fatigue-, ballistic-, and failure-type test programs to the fullest extent possible.

7-12.3 NUCLEAR HARDENING TESTS

Nuclear hardening tests are concerned with radiation and blast effects, whereas NBC tests are concerned only with nuclear particles, bacteria, and chemicals. Selected flight- and mission-critical items should be subjected to electromagnetic pulse, neutron fluence, total dose, peak gamma dose rate, thermal radiation, and nuclear air blast. Typically, these environments are simulated. For additional information concerning electromagnetic pulse and its effects on electronic components, see subpar. 7-10.3. Also see ADS-11 (Ref. 32) for additional guidance.

7-12.4 NBC TESTS

Simulant tests should be performed to reproduce an NBC contamination environment relationship to the threat environment. If NBC surety material (actual agent) tests are necessary, test methods should be described and their relationship to the simulant test correlated. Any assumptions made in the interpretations of the NBC survivability criteria are usually identified in the test plan along with their impact on the test design, procedures, and results. Component live-agent tests of the NBC filter(s) should be conducted to verify the filter absorption capability at the maximum permissible concentration specified. Live agents are actual agents. Typically, tests should be performed on the basic materials and on them in their intended operating configuration to assure NBC contamination and decontamination survivability.

7-13 COMPONENT TEST-ANALYZE-FIX-TEST

The principles of test-analyze-fix-test (TAFT), sometimes referred to as test-analyze-and-fix (TAAF), are equally applicable at the component, subsystem, and system levels. The TAFT cycle consists of subjecting the component to its intended operating environment and operating it. As failures occur or performance deficiencies are identified, analyses are performed to determine the root cause, and corrective actions are developed and implemented. Testing is resumed to verify the effectiveness of the corrective action and to uncover any remaining deficiencies. This cycle is continued throughout the component qualification program. Schedule constraints may not always allow the testing to stop for each anomaly uncovered. This practice, however, can result in deferral of corrective action incorporation and increase program risk due to uncertainties concerning the effectiveness of the corrective actions. TAFT should be included in the Airworthiness Qualification Plan (AQP) and AQS to ensure early incorporation of corrective actions and elimination of weaknesses prior to production.

7-14 MATERIAL QUALIFICATION

The requirement to qualify materials as part of the airworthiness qualification process is discussed in the subparagraphs that follow. This requirement is especially important to the use of new materials, such as plastics and composite materials, or to applications of new materials.

7-14.1 STRUCTURAL ALLOWABLES

Material design allowables are those strength requirement properties of materials used in the design. For new materials and new material applications, design allowables are generally not available in widely published references and must be determined experimentally. When it is necessary to develop data for materials, the test materials and processes should be the same as those intended for use in the production air vehicle and should represent a minimum of three batches of material. The statistical significance of experimental data should be identified, and the effects of the following should be established:

1. The variation in material properties due to the variation allowed in the time, temperature, and pressure of the cure

cycle to be used for the final component must be established.

2. The degradation due to the combined effect of temperature and humidity should be established. An experimental knockdown factor may be determined to account for this effect. The method and criteria to determine an environmental factor should be approved by the procuring activity.

ADS-35 (Ref. 5) provides guidance to determine tensile, compressive, flexural, shear, fatigue, creep, damage tolerance, and bearing strength properties. The procedures described in this ADS are for the characterization of organic matrix composite materials and are generally in accordance with the guidelines in MIL-HDBK-17 (Ref. 8).

7-14.2 ENVIRONMENTAL RESISTANCE

Because of their potential susceptibility to external environmental factors, it is imperative that composite materials be tested to ensure that they can maintain their structural properties in their intended environment throughout their required life. The resistance of composite materials to the effects of moisture, solvents, cleaners, and air vehicle fluids is determined by immersing samples in the appropriate fluid for specified times and at specified temperatures followed by testing the physical characteristics, e.g., tensile strength and flexing endurance, of the samples. It is also necessary to determine the resistance of composite materials to the effects of nuclear blast, thermal energy, and radiation; biological agents; and chemical agents, as well as to any potential adverse effects of decontamination agents. The effects of naturally occurring environmental factors, such as solar radiation, acid rain, hydrocarbons, and other unexpected normal environments, through appropriate environmental resistance tests must also be determined.

7-14.3 SPECIAL PROPERTIES

New materials, such as composite materials, may have special properties that require testing and documentation prior to use. During the curing process, if undesirable curing products are generated, it is important to identify those products and their effects. Composite materials may undergo dimensional changes after manufacture due to not only the expected temperature effects but also other factors such as humidity conditions or age. Outgassing may have detrimental effects such as forming deposits on optical surfaces and degrading optical performance.

7-14.4 PROCESS DEFINITION AND CONTROL

Essential to establishing properties of materials are the procedures and processes used to produce the material and the fabrication processes to manufacture it into a final product. For this reason, it is imperative that material processes be defined and documented in the form of process specifications and that the processes be controlled through the appropriate quality assurance procedures. In the production of metallic materials, for example, processes that impact inherent properties include the critical temperatures and cooling rates necessary to achieve proper crystalline structure. During manufacture of composite materials, for example, curing process characteristics (temperature, pressure, and time) significantly impact material characteristics. Compound effects of both material production and manufacturing must also be addressed as part of process specifications. Examples include annealing before forming and hardness treatment after forming.

7-15 PROCESS QUALIFICATION

For performance-based procurements the contractor is totally responsible for the processes and controls needed to satisfy the performance requirements of the contract and specification. The US Army requires controls for military-unique processes and those associated with flight safety parts. Process qualification is the formal procedure used to document that a specifically defined manufacturing and fabrication process produces the required repeatable performance results regardless of the manufacturer. In general, the procedure for process qualification consists of documenting the process in the form of a process specification. Process specifications identify the equipment necessary to conduct the process, the required materials, the procedures and operations (both required and recommended), the certification requirements of operators or process techniques, and the quality assurance provisions. The process specification is then applied to the specific materials intended for use in the process. Finally, tests, inspections, and verifications are conducted to determine that the process has yielded acceptable results and conforms to the requirements of the specification.

Qualification by process qualification may also be applicable to the manufacture of microcircuits in which parts of differing performance characteristics are produced by a common process with only minor changes in their overall configuration. The benefit of such an approach is that it avoids the requirement to undergo sometimes costly qualification procedures when only minor changes are made to a class of components by a common process. The risk of such an approach is that at some point a significant departure in configuration may be made that would no longer meet the original qualification criteria.

7-16 SPARES AND REPAIR PARTS QUALIFICATION

The purpose of spare and repair parts qualification is to ensure that items procured for the purpose of supplying the repair inventory are suitable for their intended function. Except when parts have been determined to be fully competitive, all parts require some type of qualification, particularly if spare and repair parts are procured from a supplier different from the original supplier of the end item. Par. 3-12 provides special requirements applicable to parts covered by a Flight Safety Parts Program. (Also see ADS-39, *Substantiation Requirements for Alternate Manufacturing Source of Helicopter Drive System Components*, (Ref. 34).)

7-16.1 BUILD TO PRINT

Build to print refers to the process of manufacturing an item to the dimensions and processes requirements of the drawing. When an item is built to print from an alternate source, it is necessary to perform a formal review in order to demonstrate that the source has the technical capability to convert the print information into a conforming item. It may also be required of a vendor after a break in production or for the production of new lots. A first article test may also be required. Performance specifications at the spare part and higher assembly level are preferred.

7-16.2 SPECIFICATION CONTROL

An item procured under specification control should undergo qualification testing to demonstrate that the vendor is capable of correctly translating the specification requirements into hardware meeting performance parameters. A first article test forms the basis for this demonstration, and in addition to being performed on the first article produced, it may also be required of a vendor after a break for production or in the production of new lots.

7-16.3 SOURCE CONTROL

Source control items are items that can be procured only from an approved source. For source control items in-system qualification testing must be performed initially since source control implies that there are unknown and intangible performance characteristics that cannot be determined by testing the repair item in isolation from its next higher assembly. This situation is an undesirable one because it also presents diagnostic and repair problems in the field. A first article test forms the basis for this demonstration, and in addition to being performed on the first article produced, it may also be required of a vendor after a break in production or for the production of new lots.

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LIST OF ACRONYMS AND ABBREVIATIONS

USAATD		US Army Aviation Applied Technology Directorate, Fort Eustis VA.
AQS	=	Airworthiness Qualification Specification
ASIP	=	Aircraft Structural Integrity Program
CDRL	=	Contract Data Requirement List
CTF	=	Contrast Transfer Function
DID	=	Data Item Description
DoD	=	Department of Defense
E3	=	Electromagnetic Environment Effects
EMI	=	Electromagnetic Interference
EMP	=	Electromagnetic Pulse
FAA	=	Federal Aviation Administration
ESD	=	Electrostatic Discharge
ESS	=	Environmental Stress Screening
FSP	=	Flight Safety Part
HSIP	=	Helicopter Structural Integrity Program
MAGW	=	Maximum Alternate Gross Weight Pulse
MRC	=	Minimum Resolvable Contrast
MRT	=	Minimum Resolvable Temperature
MTF	=	Modulation Transfer Function
NBC	=	Nuclear, Biological, Chemical
NEMP	=	Nuclear Electromagnetic
PCP	=	Parts Control Program

QDR	=	Quality Deficiency Report
QPL	=	Qualified Products List
SDGW	=	Structural Design Gross Weight